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de Vries, Gaaitzen; Chen, Quanrun; Hasan, Rana; Li, Zhigang

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Do Asian Countries Upgrade in Global Value Chains? A Novel Approach and Empirical Evidence*

Gaaitzen de Vries, Quanrun Chen, Rana Hasan and
Zhigang Li

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This paper examines the move into upstream and downstream global value chain (GVC) activities by 11 Asian countries. We use international input–output tables in combination with employment data and measure the number of workers in each country involved in manufactures GVC. Jobs are classified by business function based on occupational information, such as R&D, fabrication, logistics, sales and marketing. In most Asian countries, we find a faster employment increase in R&D and other support services relative to fabrication activities between 2000 and 2011. However, the participation in GVC and the pace of upgrading appears to differ substantially across Asian countries. We use a structural decomposition method to explore the role of trade, consumption and technological change in accounting for changes in countries' involvement in GVC.

Keywords: functional upgrading, global value chains, multi-region input–output tables, structural decomposition analysis.

JEL classification codes: D57, F16, F63.

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I. Introduction

Asia's labor force is rapidly evolving. The average years of schooling of Asia's population nearly doubled between 1970 and 2010, rising from approximately

*de Vries (corresponding author): Groningen Growth and Development Centre, Faculty of Economics and Business, University of Groningen, Room 5411.512, Nettelbosje 2, 9747 AE, Groningen, the Netherlands and University of International Business and Economics, Beijing, China. Email: g.j.de.vries@rug.nl. Chen: School of Statistics, University of International Business and Economics, Beijing 100029, PR China. Email: qrchen@amss.ac.cn. Rana Hasan: Economic Research and Regional Cooperation Department, Asian Development Bank, Mandaluyong City, Philippines, Email: rhasan@adb.org. Zhigang Li: Economic Research and Regional Cooperation Department, Asian Development Bank, Mandaluyong City, Philippines. Email: zli@adb.org. We are grateful for helpful comments from a referee and participants at the 24th International Input–Output Conference in Seoul and the ADB 2016 Key Indicators workshop in Manila. We also thank Mahinthan J. Mariasingham for his advice on the use of the ADB Multi-Region Input–output Database. The views expressed in this publication are those of the authors and do not necessarily reflect the views and policies of ADB or its Board of Governors or the governments they represent. The ADB does not guarantee the accuracy of the data included in this publication and accepts no responsibility for any consequence of their use.

4 to nearly 8 years (ADB, 2015a). In particular, the share of tertiary-educated youth (aged 15 to 29) has rapidly increased in many Asian countries. Contemporaneous to the increase in educational attainment has been the formation of production networks that cross national borders. Baldwin and Lopez-Gonzalez (2015) document the rapid emergence and expansion of 'Factory Asia'. The increasing skill level and the expansion of production networks appears at odds with the finding by Rodrik (2016) and Felipe et al. (2015) of premature deindustrialization in Asia. That is, manufacturing employment shares in Asia have recently peaked at relatively low levels of economic development. How are these trends connected? A possible answer the present paper explores is that Asian economies who educate their workforce also manage to upgrade in global value chains (GVC) and, thus, increasingly undertake more upstream and downstream service activities, such as R&D (upstream) and sales and marketing (downstream), relative to fabrication activities.

A rich body of literature already exists that uses case studies to examine upgrading development paths in Asia. This research identifies upgrading trajectories for firms, initially from focusing on fabrication to ultimately branding their own manufactures (Gereffi 1999). As firms upgrade, they acquire new functions in the GVC, such as design or marketing that require enhanced human competences (Humphrey, 2004). For example, Sturgeon and Lee (2005) describe contract manufacturers in the Taipei, China electronics industry who extended their activities from assembly to product redesign, logistics and after-sales services and repair. Thus, the increase in skills of Asia's labor force is seen as going hand in hand with upgrading in value chains. So far, however, much of this analysis has been qualitative and for selected firms or industries. What is missing is a quantitative analysis of macroeconomic upgrading trends by Asian countries in GVC.

Analyzing upgrading in GVC at a more aggregated level is not straightforward and we aim to take a first step. A major bottleneck is the empirical identification of GVC. Typically, use is made of measures of foreign direct investment, imports and exports over GDP or the share of intermediate imports in overall imports. Even when this type of data is available, it is still not capturing how activities are combined in GVC.

This paper adopts an empirical method for identifying GVC. We follow Timmer et al. (2014) and define a GVC as all activities that are directly and indirectly needed for producing a final (manufacturing) product, such as cars or electronics. We measure the participation of 11 Asian economies in manufactures GVC between 2000 and 2011. An important contribution we make is modeling the type of jobs involved in GVC as in Timmer et al. (2018). What matters for the effect of expanding production networks on domestic labor demand is the job content which can be inferred from data on the activities carried out by a country involved in GVC (Krugman, 2008).

Our analysis is an extension of research that has been done so far. Recently, researchers have measured the domestic value-added content of exports in Asia

(Koopman et al. 2012; Kwon and Ryou 2015; ADB 2015b). This provides important information on the income generated by Asian countries from participating in GVC. An increase in the domestic content of exports may signal the substitution of domestic for imported intermediate inputs. However, changes in the domestic value added of exports are not necessarily informative of upgrading in GVC as changes in the domestic content may originate from alterations that have little to do with upgrading. For example, an increase in the share of domestic value added may come from an expansion of fabrication activities or changes in the industry composition (e.g. a shift towards natural resource exports that typically have a higher share of domestic content). In addition, generating jobs (good jobs) in GVC is typically of primary concern to policy-makers.

This paper examines *functional upgrading* in GVC, defined as the integration or the movement of workers into more sophisticated business functions in GVC (Humphrey and Schmitz, 2002).¹ A typical industrial upgrading pattern would be from doing mainly assembly activities to own-equipment manufacturing to ultimately own-brand manufacturing (Gereffi, 1999). This will be reflected in an increasing number of jobs related to upstream and downstream activities by Asian countries involved in GVC. In particular, we would expect a more rapid increase in upstream activities, such as R&D and design, and downstream activities, such as sales and marketing, relative to fabrication.

As such, the perspective in this paper shifts from a pure sector focus on manufacturing towards a focus on the activities involved in creating manufactured products. Historically, industrialization has been intimately related to economic development (Felipe et al., 2015). Premature deindustrialization is, therefore, an important concern for academics and policy-makers. However, firms in Asia may have been actively pursuing support services functions in GVC, such as R&D and design instead of core fabrication activities. In addition, the re-organization of GVC increasingly appears to relate to business support functions, such as call centers, and information and communication technology support (Sturgeon and Gereffi, 2009). A focus on activities is therefore useful as it adds new information about the development paths of Asian countries.

Specifically, we use new country-industry-year-specific employment data, with information on the occupations of individuals such that jobs can be classified by business function (Timmer et al., 2018). This data is combined with the ADB's multi-regional input-output (MRIO) tables for a first step to start analyzing functional upgrading in GVC in 11 Asian economies, namely, Bangladesh, India, Indonesia, Japan, Malaysia, Philippines, China, Korea, Taipei (China), Thailand and Viet Nam, for the period from 2000 to 2011. As an extension and initial attempt to examine the drivers of these trends, we use a structural decomposition to measure the role of trade, consumption and technological change in accounting for the change in the number and type of jobs involved in GVC.

1 Other types of upgrading, such as industry, quality or product upgrading, are not the focus of this paper. See Hahn et al. (2016) for quality and product upgrading in Korea, Japan and Indonesia.

The remainder of this paper is organized as follows. In Section II, the data and GVC concept is introduced and illustrated using the China’s electronics GVC. Section III examines functional upgrading in manufactures GVC for 11 Asian countries. We then evaluate to what extent changes in jobs per function type and country can be explained by each of the different channels affecting labor demand in Sections IV (method) and V (results). Section VI provides concluding remarks.

II. Jobs in Global Value Chains: Concept, Data and Examples

II.1 Concept

The GVC approach we adopt in this paper measures the contribution of countries to global manufacturing production. It is defined as the jobs generated in a country by participating in global production of a particular set of products, abbreviated by the terms ‘GVC jobs’, for global value chain jobs (Timmer et al., 2014). Meng et al. (2015) label this approach a backward industrial-linkage based decomposition as it identifies all stages of a final good or service in a GVC. It answers the question of how much jobs a country adds to the global production of a particular set of final products.

A particular row in Figure 1 provides information on the jobs from a particular country-industry to all GVC in the world. Obviously, this includes jobs in the production of its own final products, but also jobs for production in other GVC, by means of delivering intermediate inputs.

Figure 1 An accounting framework for global value chains

			Final products of a global value chain, identified by country -industry of completion							Jobs
			Country 1		...	Country M				
			Industry 1	...	Industry N	...	Industry 1	...	Industry N	
Jobs from country - industries participati ng in global value chains	Country 1	Industry 1								
		...								
		Industry N								
								
	Country M	Industry 1								
		...								
Industry N										
Total jobs for each GVC										World jobs

Notes: Cell values represent the jobs generated in the country-industry given in the row, within the global value chain corresponding to the country-industry of completion given by the column. Source: Modification of figure 1 in Timmer et al. (2014)

It is important to note that a country's manufactures GVC jobs reflects work related to a particular set of activities; namely, those directly and indirectly related to the production of final manufactures. This includes activities in the manufacturing sector itself but also in supporting industries such as business, transport and communication and financial services through the delivery of intermediate inputs. These indirect contributions will be explicitly accounted for through the modeling of input–output linkages across sectors.

Consider the example of electronic products, where the final stage of production takes place in China. Demand for Chinese electronics will in the first instance raise the output of the Chinese electronics industry. However, production in this industry relies on parts and components that are produced elsewhere, such as batteries, computer chips and touchscreens, as well as energy and various business services such as logistics, transport, marketing and financial services. These intermediate goods and services need to be produced as well, thus raising output in the industries delivering these: say, the US business services industry, the hard disc drive from Korea's electronics industry and the processor from Japan's electronics industry.

In this section and the next we focus on the contribution to the global production of final manufacturing goods, denoted by the term 'manufactures'. Production systems of manufactures are highly prone to international fragmentation, as activities have a high degree of international contestability: they can be undertaken in any country with little variation in quality. GVC jobs of a country are then defined as the contribution of its industries to the global production of manufactures (Timmer et al., 2013). The GVC jobs of a country in global production of manufactures is equal to the sum of jobs by all its industries to the production of all final manufacturing goods where the last stage of production takes place in any country in the world.

To model these international production linkages, we rely on a fundamental input–output identity introduced by Leontief (1936). However, in contrast to Leontief's use of a national input–output table, we consider his input–output identity in a multi-country setting as production processes are unbundled across national borders. Leontief's identity states that:

$$\mathbf{q} = \mathbf{B}\mathbf{q} + \mathbf{f},$$

where \mathbf{q} denotes outputs, \mathbf{f} is final consumption and \mathbf{B} is a world input–output matrix with intermediate input coefficients. The matrix describes how a given product in a country is produced with different combinations of intermediate inputs from anywhere in the world. The identity states that a good is either used as an intermediate input in another production process or consumed. This identity can be rewritten as:

$$\mathbf{q} = (\mathbf{I} - \mathbf{B})^{-1}\mathbf{f},$$

with \mathbf{I} an identity matrix.² $(\mathbf{I} - \mathbf{B})^{-1}$ is the Leontief inverse. It represents the total production value that is directly and indirectly required to produce for final demand. To see this, let \mathbf{z} be a vector column with the first element representing the global consumption of iPads produced in China, and the rest zeros. This is the total final output of the Chinese iPad industry. Then \mathbf{Bz} is the vector of *direct* intermediate inputs, both Chinese and foreign, needed to assemble iPads in China, such as hard disc drive, batteries and processors. However, these intermediates need to be produced as well. $\mathbf{B}^2\mathbf{z}$ indicates the intermediate inputs directly needed to produce \mathbf{Bz} , and so on. Thus, $\sum_{n=2}^{\infty} \mathbf{B}^n\mathbf{z}$ represents all intermediate inputs indirectly needed for the iPad production. By adding the final output to all direct and indirect intermediate input requirements, the total gross output value related to the production of final output \mathbf{z} is given by $\mathbf{z} + \mathbf{Bz} + \sum_{n=2}^{\infty} \mathbf{B}^n\mathbf{z} = \sum_{n=0}^{\infty} \mathbf{B}^n\mathbf{z} = (\mathbf{I} - \mathbf{B})^{-1}\mathbf{z}$.

We can use this insight to derive GVC jobs from any final output value. Let \mathbf{g} be the direct amount of jobs by function per unit of gross output. Elements in the vector \mathbf{g} are country and industry specific. For example, one element in vector \mathbf{g} is the amount of fabrication workers in the Chinese electronics industry to produce one dollar of gross output. The elements in \mathbf{g} are direct jobs in the industry, as they do not account for jobs embodied in intermediate inputs used by the industry (say the hard disc drive from Korea's electronics industry or the processor from Japan's electronics industry; these industries are other elements in the vector \mathbf{g}). To measure all direct and indirect jobs, we need to define a matrix $\mathbf{A} = \hat{\mathbf{g}}(\mathbf{I} - \mathbf{B})^{-1}$, where \mathbf{A} is the matrix of jobs per unit of final demand; $\hat{\mathbf{g}}$ is a diagonal matrix generated from vector \mathbf{g} . Note that, as above, we use the Leontief inverse such that \mathbf{A} includes both direct and indirect jobs. The total *amount* of jobs that can be attributed to observed levels of final demand can then be found by:

$$Jobs_{i,b} = \mathbf{u}_i \hat{\mathbf{g}} (\mathbf{I} - \mathbf{B})^{-1} \mathbf{f}, \quad (1)$$

where $Jobs_{i,b}$ are the total jobs in country i by business function b , \mathbf{f} is an m -vector with final demand levels for each of the n products delivered by each of the m countries, \mathbf{g} contains the direct amount of jobs by function b per unit of gross output, and \mathbf{u}_i is an appropriately chosen summation vector. It contains ones in the cells associated with the industries in country i and zeros in the other cells.

2 See Miller and Blair (2009) for an introduction to input-output analysis. Matrices are indicated by boldfaced capital letters (e.g. \mathbf{B}), vectors are columns by definition and are indicated by boldfaced lowercase letters (e.g. \mathbf{q}), and scalars (including elements of matrices or vectors) are indicated by italicized letters (e.g. $Jobs_{i,b}$). A prime indicates transposition (e.g. \mathbf{u}'_k). A hat (e.g. $\hat{\mathbf{g}}$) indicates a diagonal matrix, with the elements of the vector \mathbf{g} on the diagonal.

II.2 Data

To carry out the empirical analysis, countries have to be included in an international input–output table. These kinds of tables can be regarded as a set of national input–output tables that are connected with each other by bilateral international trade flows. They provide comprehensive summaries of all transactions in the global economy between industries and final users across countries in a particular year. There are several international input–output tables available. They are similar in the sense that they provide comprehensive summaries of all transactions in the global economy between industries and final users across countries in a particular year. The tables differ with respect to the data sources, construction philosophy and the selection of countries distinguished (see Dietzenbacher and Tukker (2013) for further discussion and an overview of existing international input–output tables).

For the GVC analysis in the first part of this paper, we use the multi-region input–output tables developed at the Asian Development Bank (ADB MRIO; see Mariasingham, 2015). The ADB MRIO include more Asian countries in the world input–output tables (WIOT) from the 2013 release of the World Input–output Database project (see Timmer et al., 2015). This is to facilitate analysis related to the Asia and Pacific region. Five Asian countries (Bangladesh, Malaysia, the Philippines, Thailand and Viet Nam) have been added for the years 2000, 2005, 2006 and 2011. A country is ‘added’ to WIOT by splitting intermediate input and final demand flows from the Rest of the World block in the WIOT into the country and all other countries included in the Rest of the World. This requires detailed information on production, consumption and trade flows of the country that is ‘added’. The distinction of additional Asian countries in the ADB MRIO comes on top of the Asian countries that are already available in the WIOT; namely, China, Japan, Korea, India, Indonesia and Taipei, China. Because the ADB MRIO is comparable to WIOT except that more countries are distinguished, the empirical results presented in the next subsection and in Section III are comparable when using either the ADB MRIO or the 2013 release of WIOT.³ The international input–output tables provide the information for matrix **B** and vector **f** in Equation (1).

To account for the drivers of changes in jobs in Sections IV and V of this paper, we apply a structural decomposition method. This structural decomposition analysis requires international input–output tables in constant prices to allow for the analysis to be based on changes in volumes. That is, if we were to use tables in current prices the results might be driven by changes in output prices instead of changes in employment and output volumes. Tables in previous years’ prices are available in the 2013 release of the WIOD project and not in

3 Note that the ADB MRIO and the WIOT are not exactly identical as the distinction of additional Asian countries in the ADB MRIO requires rebalancing of the entire international input–output table.

the ADB MRIO and only up until 2009 (Timmer et al., 2015). This restricts the countries included in the decomposition analysis. Deflation of international input–output tables is not straightforward as it requires proper deflation of all cells in the matrix of intermediate input flows between country-industries and the matrix of final demand flows. We account for the drivers of changes in jobs for a more limited set of Asian economies; namely, China, Japan, Korea, India, Indonesia and Taipei, China.

The MRIO tables are an important improvement on the existing statistical framework, because they allow one to examine and study the implications of global production fragmentation. However, there is substantial scope for improving these tables. Timmer et al. (2015) discuss possible improvements and extensions of the tables. One particular limiting assumption in the tables is the assumption of firm homogeneity within industries. A column in a MRIO table only provides the average production structure across all firms in a particular industry. However, these production structures might be rather different for various types of firms. For example, Chen et al. (2012) and Koopman et al. (2012) found that for China the import content of exports differed substantially between foreign processing firms and domestic firms. Likewise, there are differences in trade and interindustry relations between formal and informal firms. Typically, informal firms are less active in exporting goods directly and often also indirectly. Hence, using average production structures across all firms in an industry may imply that the employment effects are exaggerated. Incorporating information on heterogeneity in production processes from firm-level data is an important avenue for future work because aggregation errors in value chain analyses would be reduced.

Information on jobs classified by business function is obtained from population censuses and labor force surveys, documented in Timmer et al. (2018). For the countries that are included in the WIOD project, detailed socioeconomic accounts are already available. We used these for information on total persons engaged by country-industry. This data is available annually from 1995 until 2011.

To split persons engaged in each country-industry by business function, we use information on the occupations of workers (see Timmer et al. 2018 for further discussion). A key element in this approach is the mapping of occupations to business functions. For that, Timmer et al. (2018) use the list of functions distinguished by Sturgeon and Gereffi (2009), which itself is derived from a list of generic business functions first proposed by Porter (1985).

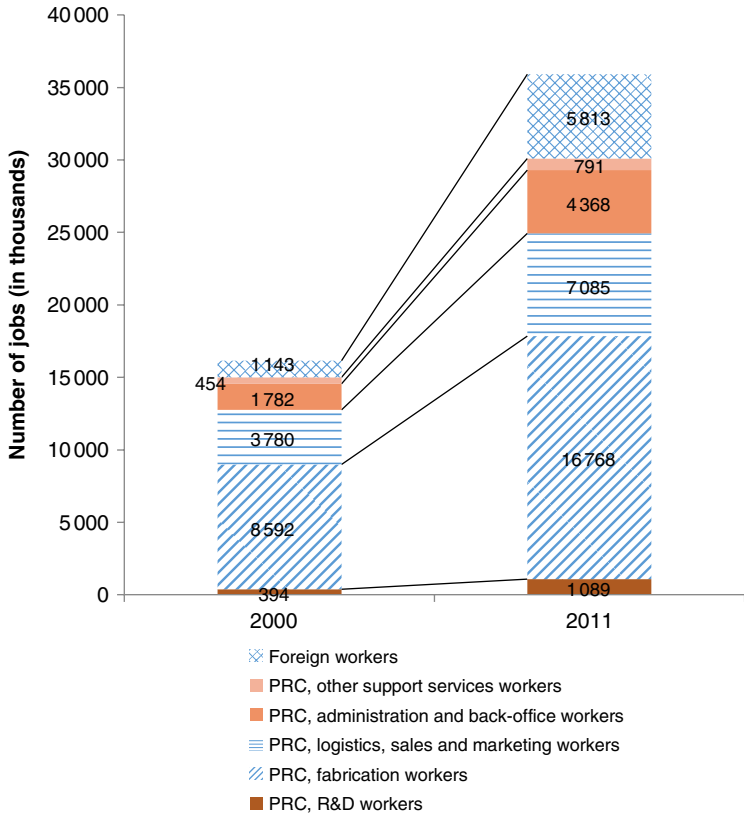
For the 5 additional Asian countries included in the ADB MRIO, we estimated jobs by business function, where we closely followed the approach by Timmer et al. (2018). For Bangladesh, the Philippines, Viet Nam and Thailand, we used labor force surveys, whereas for Malaysia we used population census data. We applied the resulting business function shares to employment estimates by industry to obtain the number of jobs by function. Employment by broad sectors was obtained from the ADB Key Indicators. Value added by industry is

available from the ADB MRIO. To disaggregate the employment data to the same industry detail, we assumed the same labor productivity within broad industries. This provides the information for vector \mathbf{g} in Equation (1).

II.3 Global value chain example

Figure 2 shows an illustration of the GVC concept for electronic products finalized in China. Basically, the GVC of electronics equipment in China is presented in a column in Figure 1 and the rows in that column give the jobs originating from a country-industry participating in the Chinese electronics GVC.

Figure 2 Global value chain (GVC) jobs in electronic products finalized in China



Notes: The number of workers directly and indirectly involved in production of electronic products finalized in China (ISIC rev 3.1, industry 30 t33), decomposed into foreign and domestic workers by business function are shown. Sources: Authors' calculations based on the ADB MRIO, socioeconomic accounts of WIOD and occupation information from the China 2000 and 2010 population census

Our findings suggest that increased demand for Chinese electronic products resulted in an increase in jobs in China, from approximately 15 million in 2000 to 30 million in 2011. Note that these are jobs both directly as well as indirectly involved in the production of Chinese final electronic products and, hence, these jobs can originate from industries outside of electronics manufacturing itself, an issue to which we return in the next section. Information on business functions provides insight into GVC upgrading patterns. That is, if a country manages to upgrade from assembly to doing its own R&D and design activities in a GVC, this will be reflected by changes in the number of jobs from those business functions in that GVC.

Carrying out business functions in GVC is related to education, but imperfectly so. Business functions at both ends of the GVC (R&D and design at the upstream end, and logistics, sales, marketing and other super services activities at the downstream end) are typically associated with higher skill requirements. However, educational attainment need not be connected to the job or tasks that a person carries out. For example, for the USA, the share of college graduates involved in engineering was 62 percent in 2007 and the remainder consisted of workers with less than a college degree (based on data from the 2007 American Community Survey). In addition, the quality of education may be rather poor. The ADB (2015a) shows a mapping of occupations and tasks to skills and education and measures skill mismatches. Using occupation data is more appropriate if skill mismatches are pervasive.

Our findings suggest rapid growth in the amount of China's R&D workers involved in the electronics GVC of China. This growth was faster compared to growth of fabrication workers and administration and back-office workers. In addition, other support services workers expanded from approximately 454 000 in 2000 to 791 000 in 2011. However, it should be noted that most GVC jobs in 2011 still relate to fabrication (16.8 million workers) and back-office (7.1 million) activities, reflecting China's strong comparative advantage in these activities.

III. Trends in Functional Upgrading in Global Value Chains

This section describes aggregate trends in the distribution of jobs in GVC using the method that was introduced in the previous section. We will use the ADB MRIO in this section.⁴ We will use the term 'manufactures' to denote all production activities that are directly or indirectly involved in the production of final manufacturing goods. Production of manufacturing products is prone to international fragmentation as many activities have a high degree of international 'contestability'; that is, they can be undertaken in any country, usually

4 Calculations using the WIOT instead of the ADB MRIO indicate that the main trends identified here do not differ substantially for Asian countries distinguished in the WIOT.

with little variation in quality (Timmer et al., 2013). It is important to note that GVC of manufactures do not necessarily include all activities in the manufacturing sector, and neither all activities that are internationally contestable. Some activities in the manufacturing sector are geared towards production of intermediates for final non-manufacturing products and services and are not part of manufactures GVC, such as the use of cement in the construction industry. In contrast, GVC of manufactures also include jobs outside the manufacturing sector, such as business services, transport and communication, finance, and raw materials production. These indirect contributions will be explicitly accounted for through the modeling of input–output linkages across sectors.

To show this empirically, we use the number of workers per unit of output to trace the number of workers directly and indirectly involved in the production of manufacturing goods and show their sector of employment. Results are shown in Table 1. Columns (1) and (2) show the share of GVC jobs in total employment. The next four columns show the sectorial employment structure, where we distinguish between agriculture, manufacturing and other sector jobs. The final four columns show the change in jobs by sector over the period from 2000 to 2011.

The first two columns in Table 1 are indicative of the importance of manufacturing GVC in providing jobs across Asia. The findings suggest substantial differences across countries. In several high-income East Asian countries, namely Japan, Korea and Taipei, China, the employment share of GVC workers declined. For Korea, we observe a shift in employment of GVC workers, away from the manufacturing sector and towards the services sector (see the final columns in Table 1). For Japan, there has been a decline in manufactures' GVC workers across all sectors of the economy.

In other Asian countries, such as Bangladesh, India, the Philippines, China and Viet Nam, the share of manufactures' GVC workers increased. In Bangladesh, the increase was particularly rapid, from 23.7 percent in 2000 to 43.9 percent in 2011. This may be overstated. In Section II we discussed how multi-regional input–output tables do not adequately account for firm heterogeneity, in particular by properly including interindustry linkages for informal (often agricultural) firms. In addition, substantial differences in productivity between agriculture and non-agricultural sectors will be reflected in a large amount of agricultural workers involved in manufactures GVC. Excluding agricultural GVC workers still indicates that GVC workers as a share of all workers in the economy expanded in Bangladesh, but the level and pace is substantially lower: approximately 14 percent in 2000, increasing to 23 percent in 2011. For India and China, it appears the increase in GVC workers mainly originates in the manufacturing sector, adding approximately 17 million jobs in India between 2000 and 2011 and almost 24 million in China. By 2011, twice as many GVC jobs were generated in China as compared to India (245 million vs 132 million). In several countries, such as Indonesia, Malaysia and Thailand, the share of manufactures GVC workers declined, but the final columns indicate that the absolute amount of GVC workers increased.

Table 1 Manufactures GVC jobs by sector, 2000 and 2011

	Manufactures GVC workers as (%) share of all workers in the economy		Manufactures GVC workers in 2011 (in thousands) employed in				Change in manufactures GVC workers between 2000 and 2011 (in thousands) employed in			
	2000	2011	AGR	MAN	SER	ALL	AGR	MAN	SER	ALL
Bangladesh	23.7	43.9	11 187	5640	6916	23 743	7379	2619	4520	14 518
India	26.2	27.5	51 518	52 030	28 622	132 170	-2,303	17 005	8125	22 827
Indonesia	28.6	24.5	13 979	8050	6103	28 132	142	446	811	1399
Japan	20.8	17.5	1323	5177	3590	10 089	-292	-2631	-551	-3474
Malaysia	35.3	30.9	740	1425	1625	3791	179	-147	484	516
Philippines	29.4	31.2	6376	2267	2951	11 594	1825	346	1340	3510
China	27.7	30.3	104 554	88 520	52 109	245 183	5705	23 877	15 905	45 487
Republic of Korea	27.6	23.8	609	2833	2316	5757	-436	-182	535	-83
Taipei, China	30.8	28.3	122	1897	1014	3033	-50	17	109	76
Thailand	41.5	35.6	6811	3730	3020	13 560	-592	350	813	571
Viet Nam	24.8	33.1	8755	4448	3461	16 663	3172	2143	2041	7357

Notes: Global value chain (GVC) workers are directly and indirectly involved in the production of manufacturing goods. First columns show the number of GVC workers in the total economy. The next four columns indicate the total number of GVC workers by sector in 2011. The final four columns indicate the change in the number of GVC workers by sector between 2000 and 2011. AGR, agriculture; MAN, manufacturing; SER, other (mainly services) sectors

Sources: Authors' calculations based on ADB multi-regional input-output and employment data

Aggregate changes in jobs are informative about the involvement of countries in GVC. However, to examine whether countries are upgrading in GVC we need additional information.

A focus on activities in GVC may be informative for discussions about the middle-income trap. One view on this trap is that Asian countries' involvement in GVC has been successful to the extent that fabrication activities expanded and production techniques were emulated. However, the switch from imitation to innovation is difficult and if countries do not succeed, they will be stuck at middle income levels. Macroeconomic measurement of upstream (R&D, design) and downstream (sales and marketing) activities in GVC helps inform regarding the pace and character of GVC participation by Asian economies.

Across Asian countries a first distinction is made between high-income and emerging Asian countries. From Table 2 we observe that the change in GVC jobs in Korea is unevenly spread. In particular, the number of fabrication workers declined by 538 000 between 2000 and 2011, whereas employment in upstream and downstream business functions increased. These relative trends are also observed for Japan and Taipei, China. This suggests functional upgrading in GVC by high-income Asian countries.

In most emerging Asian countries, there was a formidable increase in fabrication workers between 2000 and 2011. In absolute numbers, India and China stand out (an increase of approximately 12 and 25 million fabrication workers, respectively), but also in Bangladesh, the Philippines and Viet Nam we observe a substantial increase in GVC fabrication workers. Our findings suggest that China does a much better job in generating GVC fabrication jobs compared to India (178 million in China in 2011 vs 97 million in India). It is important to upgrade in GVC, but it is also important for emerging Asian countries to provide jobs for its large less-skilled workforce. China appears to be better able to do so.

In emerging Asian countries, the number of workers in upstream and downstream GVC increased. This increase was faster compared to the increase in fabrication jobs, suggesting an upgrading process in GVC by emerging countries, although from low initial levels.

Figure 3 shows changes in employment shares by function, based on the information provided in Table 2. Several additional insights emerge from this figure. First, although the number of fabrication workers involved in manufactures GVC increased in most Asian countries, the employment shares decreased. The increase in the share of fabrication jobs in Bangladesh appears an important exception to this overall trend. Second, in most Asian countries the share of R&D workers, logistics, sales and marketing workers, and administration and back-office workers increased. This is further indicative evidence of functional upgrading in GVC by Asian countries. However, the share of workers involved in upstream and downstream activities only appears to substantially increase in Korea and Taipei, China. This suggests that an upgrading process is ongoing across Asia, but proceeding at different speeds.

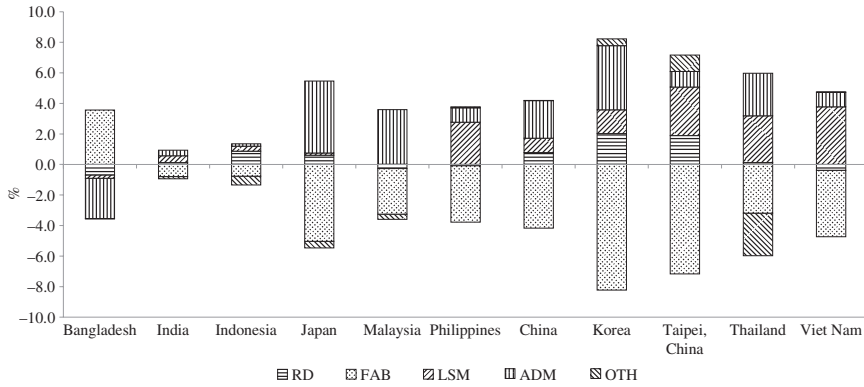
Table 2 Manufactures GVC workers by business function, 2000 and 2011 and change (in thousands)

	R&D workers		Fabrication workers		Logistics, sales and marketing workers		Administration and back-office workers		Other support services workers	
	2011	Change 2000–2011	2011	Change 2000–2011	2011	Change 2000–2011	2011	Change 2000–2011	2011	Change 2000–2011
Bangladesh	551	272	17 318	10 918	3340	2023	2530	1304	3	0.4
India	1507	722	97 466	12 046	19 157	3943	3706	997	10 334	5259
Indonesia	321	247	26 436	1111	366	107	639	73	369	–138
Japan	534	–102	5464	–2564	1525	–504	2313	–158	254	–146
Malaysia	249	25	1977	172	695	95	629	203	240	21
Philippines	196	52	8711	2339	1956	816	624	265	106	38
China	4779	2451	178 296	24 738	35 865	8525	22 007	8984	4236	789
Korea	289	114	3943	–538	533	84	837	234	156	24
Taipei, China	141	60	1846	–166	524	107	350	39	172	36
Thailand	197	26	9998	57	1665	475	1448	431	324	–346
Viet Nam	797	316	12 296	5,024	2429	1424	1138	591	2	2

Notes: GVC workers directly and indirectly involved in the production of manufacturing goods

Sources: Authors' calculations based on ADB multi-regional input–output and information on workers by business function (see main text)

Figure 3 Change in employment share of global value chain workers by function (2000 to 2011, in percentage points)



Notes: ADM, administrative and back-office; FAB, fabrication; LSM, logistics, sales and marketing; OTH to other support services; RD, R&D workers

IV. Accounting for the Drivers of Functional Upgrading: Method

In this and the subsequent section we seek to examine drivers of the changes in GVC workers by business function observed in the previous section. This section presents an adaptation of the structural decomposition method introduced by Los et al. (2013) to examine the role of trade, technological change and other factors in accounting for functional upgrading in Asian countries. Instead of looking at jobs by educational attainment as in Los et al. (2013) or routine task intensity as in Reijnders and de Vries (2018), we examine changes in jobs by business function which speaks more closely to the issue of functional upgrading in GVC.

We explicitly frame the quantification of changes in jobs in a setting with internationally fragmented GVC. Remember that in Equation (1) we derived the total *amount* of jobs that can be attributed to observed levels of final demand in a particular year:

$$Jobs_{i,b} = \mathbf{u}_i \hat{\mathbf{g}} (\mathbf{I} - \mathbf{B})^{-1} \mathbf{f}.$$

In what follows, we specify determinants of intertemporal changes in $Jobs_{i,b}$ that affect the product $\hat{\mathbf{g}}(\mathbf{I} - \mathbf{B})^{-1}$ and determinants that affect \mathbf{f} . The former effects relate to changes within GVC, whereas the latter are associated with changes in the relative weights of GVC.

We initially look at demand for final products and trade in final products. We consider three determinants that account for changes in \mathbf{f} . First, total final demand in countries increases as they grow richer. Second, the composition of consumption bundles can change due to Engel effects. If consumers become wealthier in China it is likely that their consumption bundle changes, for

example increasing their demand for cars. Finally, market shares of countries in selling final products might change over time. For example, relocation of electronics assembly activities in Japan to China will imply that market shares of Chinese final electronics products will increase at the expense of market shares of Japanese final electronics products. These three factors can be incorporated into the analysis by expressing the final demand vector as:⁵

$$\mathbf{f} = [\mathbf{T}^* \circ (\mathbf{S}^* \cdot \mathbf{c})] \mathbf{u}, \quad (2)$$

where \mathbf{c} is an m vector. Its typical element c_i contains total final demand exerted by country i . \mathbf{S}^* is an $mn \times m$ matrix constructed by stacking $m \times m$ matrices of final demand shares for each of the n outputs. \mathbf{S}^* reflects consumption bundles of countries. The rows of the $n \times m$ matrices that together form \mathbf{S}^* are obtained by aggregating over final goods supplied by each of the trade partners: if Chinese consumers were to spend 0.1 of their total consumption on Chinese food and 0.05 of their total consumption on Thai food, the share of food in Chinese consumption would amount to 0.15. \mathbf{T}^* is an $m \times n \times m$ matrix of final product trade coefficients. It reflects market shares of countries in selling final products. It is constructed by stacking m rows of $n \times m$ matrices. The typical element t_{ij} in the k th $n \times m$ matrix represents the share of country k in final demand for product i in country j . \mathbf{u} is an m -elements summation vector consisting of ones.

Equation (2) indicates how three factors together determine the relative importance of mn GVC, a GVC being defined as all activities required to produce the final product of an industry in a country. If jobs by activity would vary across GVC, changes in relative importance of these chains could lead to changes in the amount of these jobs. Within such GVC, however, technological change and changes in the type of activities countries specialize into can also lead to differences in the amounts of jobs in the country considered. If the production of final products is a fragmented process organized in GVC, the mn vector $\mathbf{g}^w \equiv \mathbf{g}'(\mathbf{I} - \mathbf{B})^{-1}$ gives a more appropriate measure of the jobs by activity to produce final products. \mathbf{g}^w gives the worldwide jobs by function used to produce one unit of each of the mn final products, irrespective of the location of the activities required.

Changes in \mathbf{g}^w would reflect biased technological change only if labor is equally productive across regions. Loosely speaking, if the productivity of a worker in country A is double that of a worker in country B and an activity is relocated from A to B, we would observe technological change biased towards that activity. To correct for this, we introduce an mn -productivity vector $\boldsymbol{\pi}$, the typical element of which contains the industry-specific labor productivity levels

5 The symbol \circ stands for the 'Hadamard product', obtained by cell-by-cell multiplication (i.e. $\mathbf{W} = \mathbf{X} \circ \mathbf{Y}$ means that $w_{ij} = x_{ij}y_{ij}$, for all i and j).

of labor relative to levels in the USA.⁶ This allows us to specify a GVC's technology in terms of labor measured in efficiency units, $\mathbf{g}^{*'} \equiv (\boldsymbol{\pi} \circ \mathbf{g})' (\mathbf{I} - \mathbf{B})^{-1}$.

It is important to note that the values in the cells of the matrix $(\mathbf{I} - \mathbf{B})^{-1}$ are not only determined by the technical production requirements in terms of intermediate inputs but also by the shares of these intermediate inputs delivered by each of the potential countries-of-origin. As a consequence, some industries in some countries will use more labor of a particular business function than expected on the basis of $\mathbf{g}^{*'}$, while others will use less. Because a WIOT represents mn industries with jobs and mn GVC to which these jobs relate, we can compute an $mn \times mn$ matrix with shares of each of the mn industries in total jobs per unit of final demand produced by a GVC. Rows correspond to industries where jobs originate; columns correspond to the GVC to which jobs contribute:

$$\mathbf{R} = \left\{ \hat{\boldsymbol{\pi}} \hat{\mathbf{g}} (\mathbf{I} - \mathbf{B})^{-1} \right\} (\hat{\mathbf{g}}^*)^{-1} \quad (3)$$

Writing $\hat{\mathbf{g}}(\mathbf{I} - \mathbf{B})^{-1} = \hat{\boldsymbol{\pi}}^{-1} \mathbf{R} \hat{\mathbf{g}}^*$ and substituting Equations (2) and (3) into Equation (1), we can express the $Jobs_{i,b}$ in period 0 in a country as:

$$Jobs_{i,b,0} = \mathbf{u}'_i \hat{\boldsymbol{\pi}}_0^{-1} \mathbf{R}_0 \hat{\mathbf{g}}_0^* [\mathbf{T}_0^* \circ (\mathbf{S}_0^* \cdot \hat{\mathbf{c}}_0)] \mathbf{u}. \quad (4)$$

Next, the difference in jobs of a country at two points in time ($Jobs_{i,b,1} - Jobs_{i,b,0}$) can be disaggregated into:

$$Jobs_{i,b,1} - Jobs_{i,b,0} = \mathbf{u}'_i \hat{\boldsymbol{\pi}}_1^{-1} \mathbf{R}_1 \hat{\mathbf{g}}_1^* [\mathbf{T}_1^* \circ (\mathbf{S}_1^* \cdot \hat{\mathbf{c}}_1)] \mathbf{u} - \mathbf{u}'_i \hat{\boldsymbol{\pi}}_0^{-1} \mathbf{R}_0 \hat{\mathbf{g}}_0^* [\mathbf{T}_0^* \circ (\mathbf{S}_0^* \cdot \hat{\mathbf{c}}_0)] \mathbf{u} =$$

$$\mathbf{u}'_i \langle \hat{\boldsymbol{\pi}}_1^{-1} - \hat{\boldsymbol{\pi}}_0^{-1} \rangle \mathbf{R}_1 \hat{\mathbf{g}}_1^* [\mathbf{T}_1^* \circ (\mathbf{S}_1^* \cdot \hat{\mathbf{c}}_1)] \mathbf{u} + \quad (5a)$$

$$\mathbf{u}'_i \hat{\boldsymbol{\pi}}_0^{-1} \langle \mathbf{R}_1 - \mathbf{R}_0 \rangle \hat{\mathbf{g}}_1^* [\mathbf{T}_1^* \circ (\mathbf{S}_1^* \cdot \hat{\mathbf{c}}_1)] \mathbf{u} + \quad (5b)$$

$$\mathbf{u}'_i \hat{\boldsymbol{\pi}}_0^{-1} \mathbf{R}_0 \langle \hat{\mathbf{g}}_1^* - \hat{\mathbf{g}}_0^* \rangle [\mathbf{T}_1^* \circ (\mathbf{S}_1^* \cdot \hat{\mathbf{c}}_1)] \mathbf{u} + \quad (5c)$$

$$\mathbf{u}'_i \hat{\boldsymbol{\pi}}_0^{-1} \mathbf{R}_0 \hat{\mathbf{g}}_0^* [\langle \mathbf{T}_1^* - \mathbf{T}_0^* \rangle \circ (\mathbf{S}_1^* \cdot \hat{\mathbf{c}}_1)] \mathbf{u} + \quad (5d)$$

$$\mathbf{u}'_i \hat{\boldsymbol{\pi}}_0^{-1} \mathbf{R}_0 \hat{\mathbf{g}}_0^* [\mathbf{T}_0^* \circ (\langle \mathbf{S}_1^* - \mathbf{S}_0^* \rangle \cdot \hat{\mathbf{c}}_1)] \mathbf{u} + \quad (5e)$$

$$\mathbf{u}'_i \hat{\boldsymbol{\pi}}_0^{-1} \mathbf{R}_0 \hat{\mathbf{g}}_0^* [\mathbf{T}_0^* \circ (\mathbf{S}_0^* \cdot \langle \hat{\mathbf{c}}_1 - \hat{\mathbf{c}}_0 \rangle)] \mathbf{u}. \quad (5f)$$

In a nutshell, this disaggregation identifies six determinants of changes in a country's jobs between the initial period (denoted by subscript 0) and the final period (denoted by subscript 1). Below, these six determinants are grouped into those arising from changes in trade, technology and consumption patterns. The

6 The elements of $\boldsymbol{\pi}$ can change over time but are assumed to be identical across workers.

decomposition technique allows us to isolate the partial effects of each of these determinants. Furthermore, the disaggregation is exhaustive. Hence, the total change in a country's jobs is attributed to changes in trade, technology or consumption. We describe each of the drivers of a country's jobs in turn.⁷

Trade

1. *Changes in the location where intermediates are produced* (Equation 5b). If some of the intermediate inputs were initially purchased from domestic suppliers but are now bought in a foreign country, the associated jobs will also be relocated to the foreign country.
2. *Changes in the location of final assembly* (Equation 5d). If the production of a final good from a country loses world market share, jobs in all countries that contributed to the production of that final good will fall. Changes in preferences of consumers may cause such changes, but also decisions by lead firms to relocate their assembly activities.

Technology

3. *Changes in global value chain jobs* (Equation 5c). We define the GVC jobs for a final good produced in a country (say the iPads in China) as the jobs anywhere in the world and in any industry required to produce US\$1 m of final output of the final good in that country. Increased efficiency in this GVC will, *ceteris paribus*, lead to lower demand for jobs of a particular activity.
4. *Changes in efficiency of a country* (Equation 5a). If productivity in a country catches up to the productivity leader (say the Chinese electronics industry catches up to US electronics), fewer jobs are needed to produce the same amount of output.

Consumption

5. *Changes in the consumption bundle* (Equation 5e). If the composition of the consumption bundle (both at home and abroad) changes, this affects the relative demand for final products. Because final products differ in terms of their embodied jobs, these Engel effects induce changes in jobs in a country.

7 The decomposition analysis represented by Equations 5a–f is not a unique solution. It alters with the choice of weights applied to the individual expressions and can give rise to $n!$ possible decompositions (see Dietzenbacher and Los, 1998). The results presented in the next section are an arithmetic average over Equations 5a–f and the so-called polar form, which consists in switching initial and final year weights in all the equations. Dietzenbacher and Los (1998) demonstrate that the average of all the potential decompositions roughly corresponds to the average of the two polar decompositions.

6. *Changes in consumption levels* (Equation 5f). Demand for final goods increases if consumers become wealthier and purchase more goods and services.

V. Accounting for the Drivers of Functional Upgrading: Results

This section presents the main results from the decomposition analysis. We focus on quantifying the actual changes in demand for workers across business activities in manufactures GVC. Changes in jobs are split into the changes in the various drivers using the decomposition methodology discussed in the previous section.

Table 3 shows changes in jobs by business function and an account of the drivers of these changes. The first three columns show the number of jobs by business function in 2000 and 2009 and the change between 2000 and 2009. Note that qualitative trends are similar to those shown in Table 2, but the time period is restricted due to the availability of international input–output tables that measure volume changes (see the discussion in Section II). Subsequent columns in Table 3 show drivers that account for the change in the number of jobs. That is, the sum of the columns for trade, technology and consumption is equal to the change in jobs between 2000 and 2009.

Note that these drivers are hypothetical changes holding everything else constant. For example, *ceteris paribus*, we examine the change in the number of jobs in a business function due to changes in the location of final assembly activities. This is an accounting exercise and we do not mean to imply that the components are independent of each other. For example, the relocation of intermediate fabrication activities might lead to cost savings and induce a shift in demand between GVC. See Reijnders and de Vries (2018) for further discussion of the strengths and limitations of the method.

Let us first focus on employment effects due to changes in the location of activities in GVC (in short, trade). In Table 3, the effects from trade are split into employment demand due to changes in the location of intermediate stages of production and final assembly. As expected, the relocation of intermediate stages of production is related to lower demand for fabrication workers in high-income Asian economies, such as Japan, Korea and Taipei, China. Between 2000 and 2009, China started to undertake more intermediate input stages, contributing to increased demand for approximately 9 million fabrication workers. This finding relates to Kee and Tang (2016), who document that Chinese firms have been substituting domestic for imported intermediate inputs.

Other emerging Asian economies like India and Indonesia did not see an increase in labor demand due to the relocation of intermediate production stages. *Ceteris paribus*, the relocation of intermediate stages is related to a decline of 11.5 and 3 million fabrication workers in India and Indonesia, respectively. For proper interpretation, note that the method measures the employment

Table 3 Decomposition of change in jobs by business function in manufacturing GVC (in thousand jobs)

Change accounted for by changes in:										
Country	Business activity	2000	2009	2009 minus 2000	Trade		Technology		Consumption	
					Location of intermediate stages	Location of final assembly	Efficiency	GVC technology	Consumption preferences	Consumption levels
India	RD	696	1026	330	-337	24	-69	119	103	490
	FAB	36 718	43 959	7241	-11 524	1147	-1831	-8031	4658	22 823
	LSM	3601	3790	189	-1792	108	-88	-539	417	2083
	ADM	1486	1637	151	-766	45	-49	-138	178	881
	OTH	4877	6160	1283	-5326	155	-300	2983	643	3127
Indonesia	RD	53	86	33	-14	1	10	20	-3	18
	FAB	11 009	11 718	709	-3079	319	1999	-1348	-640	3458
	LSM	223	279	56	-33	6	41	-17	-13	72
	ADM	455	464	9	-142	13	82	-60	-26	142
	OTH	101	276	174	132	2	21	-10	-7	38
Japan	RD	633	465	-167	-172	-46	69	-93	-11	86
	FAB	8224	5551	-2674	-1397	-550	874	-1897	-500	796
	LSM	1156	767	-389	-290	-64	122	-186	-67	97
	ADM	1876	1587	-290	-338	-125	218	-140	-98	193
	OTH	418	251	-168	-101	-24	43	-97	-25	36
China	RD	2275	4617	2341	762	884	-1802	369	110	2020
	FAB	79 101	111 371	32 270	8790	26 926	-46 941	-8913	-2183	54 591
	LSM	12 226	18 272	6046	2438	3726	-7624	-1675	-117	9298
	ADM	7532	10 205	2673	-2641	2293	-4315	2103	-21	5254
	OTH	3507	4310	803	1	997	-1864	-645	-22	2336
Korea	RD	137	207	70	43	10	-26	6	-13	49

Table 3 (continued)

Change accounted for by changes in:										
Country	Business activity	2000	2009	2009 minus 2000	Trade		Technology		Consumption	
					Location of intermediate stages	Location of final assembly	Efficiency	GVC technology	Consumption preferences	Consumption levels
Taipei, China	FAB	3190	2705	-485	-310	150	-435	-566	-172	847
	LSM	347	394	47	33	19	-57	-35	-24	110
	ADM	492	667	175	92	30	-98	2	-37	186
	OTH	128	159	32	32	8	-22	-19	-10	43
	RD	75	134	60	-2	-4	38	7	-7	27
	FAB	1865	1671	-194	-868	-78	686	-293	-99	459
	LSM	334	466	133	-74	-17	157	-17	-24	107
	ADM	257	328	71	-89	-13	122	-17	-16	84
	OTH	133	191	58	-14	-7	63	-18	-10	43

Notes: ADM, administrative and back-office; FAB, fabrication; LSM, logistics, sales and marketing; OTH, other support services; RD, R&D

effects of intermediate stages based on intermediate input shares (see Section IV, Equation 5b). Our findings thus suggest that the share of intermediate input activities in manufactures GVC declined in India and Indonesia, whereas it increased in China.

India and Indonesia did benefit from the relocation of final assembly activities and/or increased demand for products finalized in their economies (see Section IV, Equation 5d). This effect accounts for increased demand of approximately 1.1 million and 300 000 fabrication workers in India and Indonesia, respectively. China also benefitted from changes in the location of final assembly. Between 2000 and 2009, this relates to increased demand for approximately 27 million fabrication workers. Interestingly, our findings suggest that the demand for workers in R&D and logistics, marketing and sales activities also increased substantially. Our findings indicate that the relocation of intermediate and final stages of production is related to increased demand of approximately 1.6 million R&D workers and 6.2 million logistics, sales and marketing workers in China. This is much less apparent for India and Indonesia.

The next two columns examine labor demand effects due to changes in technology. With technological change, fewer workers are needed to produce the same amount of output. In general, the employment effects from technology tend to be larger than that from trade. This finding is consistent with other studies, including Autor et al. (2003), Los et al. (2013), Goos et al. (2014) and Reijnders and de Vries (2018). These studies focus on the biased nature of technological change, and this is also apparent in our findings. That is, technological change lowered demand for fabrication workers relatively much more compared to workers involved in upstream and downstream GVC activities in all Asian countries. For example, *ceteris paribus*, improvements in GVC technology lowered demand for fabrication workers by approximately 9 million workers in China but hardly affected (and even increased) demand for R&D jobs.

Changes in the consumption bundle also affected the relative demand for workers by business function. In China, the shift in the bundle of goods and services consumed towards more sophisticated and high-technology content products is related to lower demand for approximately 2 million fabrication workers and increased demand for approximately 110 000 R&D workers. In contrast, consumption shifts in India are related to an increased demand for approximately 4.7 million fabrication workers.

The final column in Table 3 suggests that the biggest effects on the demand for workers originate from increased consumption levels. Increased consumer demand lifts all boats: it does not substantially alter relative demand for workers by business function. Typically, the substantial increase in consumer spending more than compensates for lower demand for workers due to technological improvements. For example, *ceteris paribus*, due to improvements in efficiency, approximately 9.9 million fabrication workers were needed in India between 2000 and 2009. However, consumer spending increased such that approximately 22.8 million additional fabrication workers were needed to satisfy consumption.

VI. Concluding Remarks

This paper combines MRIO tables with new data on jobs classified by business function. It provides a macro-perspective to explore functional upgrading by Asian countries in GVC. In addition, it explores a quantification of trade, technology and other factors in accounting for changes in the number of workers involved in GVC.

Our findings suggest that countries differ in their ability to create jobs and upgrade in GVC. In particular, China generated a lot of fabrication jobs for its large less-skilled workforce, in line with its comparative advantage. However, at the same time, since 2000 we have observed substantial upgrading, reflected in a rapidly increasing number of Chinese R&D workers involved in GVC. These results appear related to the relocation of intermediate and final production stages and also technological change within GVC. Other Asian countries also appear to upgrade in GVC but at a slower pace. Furthermore, we find that high-income Asian countries (i.e. Japan, Korea and Taipei, China) specialize in upstream and downstream activities in GVC. These results thus lend support to the view that Asian economies who educate their workforce also manage to upgrade in GVC and, thus, increasingly undertake more upstream and downstream services activities, such as R&D and sales and marketing, relative to core fabrication activities.

We used international input–output data to measure jobs from all activities that are directly or indirectly needed to produce a final manufacturing product. In contrast to detailed case studies, our approach provides a macro-perspective and describes country trends. This is informative, but not without limitations. The measurement of jobs in GVC is affected by the aggregated nature of the data used in current empirical analysis. For example, products that differ in the type and amount of jobs required to produce it are aggregated but may have different end users (e.g. domestic vs foreign consumption). In addition, production processes of firms that produce for the domestic and foreign markets may differ (Timmer et al. 2015). Hence, distinguishing processing exports from regular exports and domestic use would improve estimates for countries heavily involved in global production networks. From a methodological point of view, it is well known that the various drivers identified by the structural decomposition method are interrelated (Dietzenbacher and Los, 1998); we therefore cautiously interpret the terms as being indicative. Future research may use other (econometric) approaches to explore the mechanisms underlying functional upgrading patterns in Asia.

Various related research efforts are ongoing. Researchers have started to use detailed firm-level data to study functional upgrading (see e.g. Van Assche and Van Biesebroeck, 2018). In addition, new firm-level surveys are being undertaken that measure the type of business functions that are carried out domestically and those that are offshored (Brown et al., 2014). Information of this type collected on a national scale could potentially provide a link as it identifies the

spatial distribution of activities within GVC of firms. These surveys are still in the testing phase and are not yet part of a regular statistical program. However, once they are, our hope is this will result in a more comprehensive understanding of what drives functional upgrading in GVC.

References

- Autor, D., R. J. Murnane and F. Levy, 2003, The skill content of recent technological change: An empirical exploration. *Quarterly Journal of Economics*, **118**, pp. 1279–334.
- ADB, 2015a, *A smarter future: Skills, education, and growth in Asia*. Asian Development Bank, Manila Philippines.
- ADB, 2015b, *Global value chains – Indicators for international production sharing*. Asian Development Bank, Manila, Philippines.
- Baldwin, R. and J. Lopez-Gonzalez, 2015, Supply-chain trade: A portrait of global patterns and severable testable hypotheses. *The World Economy*, **38**, pp. 1682–721.
- Brown, C., T. Sturgeon and J. Lane, 2014, *Using a business function framework to examine outsourcing and offshoring by US organizations*. IRLE Working Paper No. 121–14, University of California, Berkeley.
- Chen, X., L-K. Cheng, K-C. Fung, L-J. Lau, Y-W. Sung, K. Zhu, C. Yang, J. Pei and Y. Duan, 2012, Domestic value added and employment generated by Chinese exports: A quantitative estimation. *China Economic Review*, **23**, pp. 850–64.
- Dietzenbacher, H. W. A. and B. Los, 1998, Structural decomposition techniques: Sense and sensitivity. *Economic Systems Research*, **10**, pp. 307–23.
- Dietzenbacher, E. and A. Tukker, 2013, Global multi-regional input–output frameworks: An introduction and outlook. *Economic Systems Research*, **25**, pp. 1–19.
- Felipe, J., A. Mehta and C. Rhee, 2015, Manufacturing matters ... but it's the jobs that count. Mimeo, Asian Development Bank, Manila, Philippines.
- Gereffi, G., 1999, International trade and industrial upgrading in the apparel commodity chain. *Journal of International Economics*, **48**, pp. 37–70.
- Goos, M., A. Manning and A. Salomons, 2014, Explaining job polarization: Routine-biased technological change and offshoring. *American Economic Review*, **104**, pp. 2509–26.
- Hahn, C. S., K. Ito and D. Narjoko, 2016, Exporting and upgrading of product portfolio: Evidence from Korea, Japan, and Indonesia. *Asian Economic Journal*, **30**, pp. 349–73.
- Humphrey, J., 2004, *Upgrading in global value chains*. ILO Working Paper No. 28. International Labour Organization, Geneva, Switzerland.
- Humphrey, J. and H. Schmitz, 2002, How does insertion in global value chains affect upgrading in industrial clusters? *Regional Studies*, **36**, pp. 1017–27.
- Kee, H. L. and H. Tang, 2016, Domestic value added in exports: Theory and firm evidence from China. *American Economic Review*, **106**, pp. 1402–36.
- Koopman, R., Z. Wang and S-J. Wei, 2012, How much of Chinese exports is really made in China? Assessing foreign and domestic value-added in gross exports. *Journal of Development Economics*, **99**, pp. 178–89.
- Krugman, P. R., 2008, Trade and wages reconsidered. *Brookings Paper on Economic Activity*, Spring Issue, pp. 103–54.
- Kwon, T. and J-W. Ryou, 2015, Global value chains of East Asia: Trade in value added and vertical specialization. *Asian Economic Journal*, **29**, pp. 121–43.
- Leontief, W., 1936, Quantitative input–output relations in the economic system of the United States. *Review of Economics and Statistics*, **18**, pp. 105–25.

- Los, B., M. P. Timmer and G. J. De Vries, 2013, *The demand for skills 1995–2008: A global supply chain perspective*. OECD Economics Department Working Papers, No. 1141, OECD Publishing, Paris.
- Mariasingham, J., 2015, ADB multi-region input–output database: Sources and methods. Mimeo, Asian Development Bank, Manila, Philippines.
- Meng, B., G. Peters and Z. Wang, 2015, Tracing CO2 emissions in global value chains. IDE Discussion Paper No. 486, Institute of Developing Economies (IDE), Chiba, Japan.
- Miller, R. E. and P. D. Blair, 2009, *Input–output Analysis* (2nd edn). Cambridge University Press, Cambridge UK.
- Porter, M., 1985, *Competitive Advantage: Creating and Sustaining Superior Performance*. Free Press, New York.
- Reijnders, L. S. M. and G. J. de Vries, 2018, Technology, offshoring, and the rise of non-routine jobs. *Journal of Development Economics*, **135**, pp. 412–32.
- Rodrik, D., 2016, Premature deindustrialization. *Journal of Economic Growth*, **21**, pp.1–33.
- Sturgeon, T. and G. Gereffi, 2009, Measuring success in the global economy: International trade, industrial upgrading, and business function outsourcing in global value chains. *Transnational Corporations*, **18**, pp. 1–36.
- Sturgeon, T. and J. R. Lee, 2005, Industry co-evolution: A comparison of Taiwan and North-American electronics contract manufacturers. In: *Global Taiwan: Building Competitive Strengths in a New International Economy* (eds S. Berger and Lester R.). M. E. Sharpe, Armonk, New York.
- Timmer, M. P., E. Dietzenbacher, B. Los, R. Stehrer and G. J. de Vries, 2015, An illustrated user guide to the World Input–Output Database: The case of global automotive production. *Review of International Economics*, **23**, pp. 575–605.
- Timmer, M. P., S. Miroudot and G. J. de Vries, 2018, Functional specialization in trade. *Journal of Economic Geography*, **19**, pp. 1–30.
- Timmer, M. P., A. A. Erumban, B. Los, R. Stehrer and G. J. de Vries, 2014, Slicing up global value chains. *Journal of Economic Perspectives*, **28**, pp. 99–118.
- Timmer, M.P., B. Los, R. Stehrer and G. J. de Vries, 2013, Fragmentation, incomes and jobs. An analysis of European competitiveness. *Economic Policy*, **11**, pp. 613–61.
- Van Assche, A. and J. Van Biesebroeck, 2018, Functional upgrading in China's export processing sector. *China Economic Review*, **47**, pp. 245–62.